Lakes, Rivers, and Fish

Protocol: Freshwater Flow Systems Integrated Protocol

Parks Where Protocol Will Be Implemented: ALAG, ANIA, KATM, KEFJ, LACL

Vital Signs Addressed: Surface Hydrology, Freshwater Chemistry, Resident Lake Fish

Justification/Issues Being Addressed: Network parks contain some of the largest and most "pristine" freshwater resources in the national park system. These include the two large lakes, Naknek Lake and Lake Clark, numerous multilake systems, and thousands of miles of rivers, including five designated "Wild Rivers"—and largely unexploited resident lake fish populations. Aquatic systems in the interior of KATM and LACL are so extensive that they form the physical template upon which nearly all biological systems are organized.

In establishing these park units, Congress recognized the importance of clean water, with a specific reference to protecting and maintaining rivers and/or lakes in their natural state in the enabling legislation for ALAG, ANIA, KATM, and LACL. Legislation for KEFJ mentions the Harding Icefield—a major source of freshwater for this park and the adjacent coastal zone.

Surface Hydrology

Groundwater, lakes, and streams comprise an interconnected flow system within the broader landscape (Riera et al. 2000). As collectors of water, energy, nutrients, solutes, and pollutants from the landscape and atmosphere, lakes and streams are interactive with their adjacent environments, integrative of the biophysical processes occurring there, and thereby sensitive to local climate and to land-use changes in and adjacent to parks.

Climate warming is decreasing glacial coverage in SWAN, shortening the length of ice cover on lakes, and increasing evaporation from water and land surfaces. This appears to be changing surface hydrology which, in turn, will also influence water chemistry, availability of aquatic habitats to fish and wildlife populations, and recreational opportunities.

Measurements of discharge and lake levels are fundamental to understanding the biophysical characteristics of the SWAN park system. Water quality and fish community parameters are also directly influenced by seasonal and annual flow patterns.

Freshwater Chemistry

Water quality—especially temperature, specific conductance, pH, dissolved oxygen, turbidity and nutrients—is important for the survival, growth, and reproduction of aquatic organisms. Temperature plays an important role in physiological processes, affecting the makeup of biological communities. Changes in water temperature may indicate climate change. Specific conductance typically reflects the ionic strength or mineralization of the water. It may signal the water source, with a high specific conductance representative of a strong groundwater influence (Brabets 2002). Alterations in pH can affect major ions and cations, total organic carbon, trace metal concentrations, and biogeochemical processes, including sulfate reduction, N_2 fixation, and organic matter decomposition (Brezonik et al. 1993). In SWAN, low pH may reflect volcanic influence. Adequate dissolved oxygen is essential for the survival of most aquatic organisms, and it can also control chemical cycling. Turbidity affects visual acuity and, through algal photosynthesis, primary productivity. Nitrogen, phosphorus, silicon fluxes, and chlorophyll concentrations are measures of nutrient loading or aquatic productivity, and may be influenced by geologic (disturbance) events such as volcanic eruptions, or reflect local lithologies and biological interactions such as anadromous fish returns or increased alder (*Alnus*; a nitrogen fixer) expansion within watersheds. Dissolved organic carbon integrates watershed and water body productivity, because much of the carbon is derived from the watershed (Schindler et al. 1997). Dissolved organic carbon is generally proportional to the amount of wetlands in a watershed (Gergel et al. 1999) and is affected by climate change (Schindler et al. 1997).

Major ions, which provide important geochemical data, include the dissolved cations of calcium, magnesium, sodium, and potassium and the major anions of sulfate, chloride, and bicarbonate. Trace elements (including arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) occur naturally only in minor amounts and have important influences on primary productivity, but become toxic to biota with increased concentrations. Atmospheric deposition from anthropogenic activities is a frequent cause of increased concentrations. Alkalinity measures the susceptibility of a water body to acidification.

Because water quality in SWAN parks is relatively pristine, has very little in the way of buffering capacity, and no known anthropogenicly related variance from Alaska water quality standards, our focus will be on documenting natural variability, future changes from existing conditions, and changes due to far-field effects such as climate change and atmospheric transport of pollutants.

<u>Resident Lake Fish</u>

Resident lake fish serve an important ecological role in SWAN parks. They represent a variety of trophic levels (omnivores, insectivores, planktivores, and piscivores) and hence reflect changes that occur in the food chain. Resident fish also provide a measure of environmental contaminants in aquatic systems, such as PCBs carried into the system by spawning salmon (Krummel et al. 2003), airborne toxic trace metals deposited directly or indirectly via melting snowpack (Wania 1997), and toxic contaminants potentially produced by mining activities (e.g., proposed Pebble Mine near LACL; see [http://www.ndmpebblemine.com/]). In addition to these characteristics, resident fish are relatively easy to sample and use a wide variety of habitats, so they are well suited to serve as environmental indicators. Resident fish play important recreational, economic, and subsistence roles as well. Several species, such as rainbow trout (*Oncorhynchus mykiss*), lake trout (*Salvelinus namaycush*), northern pike (*Esox lucius*), and Arctic grayling (*Thymallus arcticus*), provide excellent recreational opportunities to local, in-state, and out-of-state anglers, which may inject significant sources of income to local and state economies. Whitefish (*Coregonus* spp., *Prosopium* spp.) and northern pike are important subsistence species for local native Alaskans.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

<u>Surface Hydrology</u>

Question:

- How are the timing and magnitude of peak river discharge and lake level changing in key SWAN glacial and nonglacial systems?

Objectives:

- Monitor maximum and minimum annual daily flow, maximum and minimum annual 3-d or 7-d duration flow, and total annual water yield in selected SWAN river systems.
- Monitor annual trends in the timing and magnitude (average, maximum, minimum) of lake levels in selected SWAN flow systems.

<u>Freshwater Chemistry</u>

Questions:

- How are the annual maximum, minimum, and average measurements for core parameters (pH, dissolved oxygen, specific conductance, and temperature) and turbidity changing?
- How are the annual degree days changing in lakes? How are summer lake stratification patterns changing?

- How are nutrient levels (nitrogen, phosphorus, silicon), chlorophyll a, and dissolved organic carbon changing as measured in midsummer?
- How are dissolved major ions, trace elements, and alkalinity changing as measured in midsummer?

Objectives:

- Observe annual and interannual variability in maximum, minimum, and average temperature, pH, dissolved oxygen, specific conductance and turbidity in selected SWAN flow systems.
- Quantify midsummer lake profiles of temperature, specific conductance, pH, dissolved oxygen, and turbidity on an annual basis for high-priority lake systems and less frequently for other SWAN lakes.
- Estimate nutrient and chlorophyll concentrations on an annual basis in high-priority lake systems and less frequently for other SWAN lakes.
- Monitor dissolved major ions, trace elements, and alkalinity on an annual basis for high-priority lake systems and less frequently for other SWAN lakes.

<u>Resident Lake Fish</u>

Questions:

- Are important recreational, subsistence, and other endemic species of resident fish persisting in SWAN lakes?
- What are the trends in relative composition of resident fish communities among key lake systems within SWAN parks?
- Do nonendemic fish species occur in key lake systems in SWAN parks, and are they increasing in distribution?
- Are bioaccumulated contaminants increasing in fish communities in SWAN lakes?

Objectives:

- Estimate occupancy of important recreational, subsistence, and other endemic species of resident fish annually within high-priority lakes and every 2-10 yr within lower priority lakes in KATM and LACL.
- Estimate long-term trends in relative species richness of resident fish communities in high-priority lake systems within SWAN parks.
- Annually monitor influx of nonendemic fish species within high-priority lakes and every 2-10 yr within lower priority lakes in KATM and LACL.
- Collect and archive tissue samples of resident fish for later biocontaminant analysis every 5 yr from within high-priority lakes and every 10-15 yr within lower priority lakes in KATM and LACL.

Basic Approach: Invited experts and SWAN park staff employed a 3-tier categorization to prioritize sampling of major lakes or streams within SWAN parks to ensure that key flow systems will be monitored annually even if I&M funding is greatly reduced. Categorization criteria included access, level of use/management issues, and ecological and spatial coverage. Tier 1 (high priority) lakes and streams offer easy access and hence receive the heaviest use and management concern. Naknek and Brooks Lakes, both containing anadromous fishes, are Tier 1 lakes representative of the Naknek flow system in KATM. Tier 1 lakes in the Lake Clark flow system in LACL include Lake Clark (anadromous) and Kontrashibuna Lake (nonanadromous). Resurrection River/Exit Creek is the Tier 1 river system in KEFJ.

Tier 2 (medium priority) lakes and rivers are less accessible than their Tier 1 counterparts, and a randomly chosen subset will be sampled less frequently (e.g., 2-5 yr). These lakes and rivers are important for expanding the spatial inference beyond Tier 1 lakes and rivers, e.g., to ensure that trends observed at Tier 1 sites are present in other flow systems in the parks. Tier 3 (low priority) lakes and rivers further expand the scale of inference, but will be sampled less frequently (e.g., 10 years), if at all, because of funding constraints. However, data for certain vital sign metrics may be collected annually at Tier 2 and 3 locations where volunteer and/or park staff are seasonally present. Tier 2 and 3 lakes and rivers, by SWAN park, are:

Tier 2
ANIA: Aniakchak River drainage, including Surprise Lake
KATM: JoJo Lake, Grosvenor Lake, Murray Lake, Hallo Lake system
LACL: Kijik Lake, Lachbuna Lake, Crescent River system
KEFJ: Delusion Lake, Nuka River

Tier 3
KATM (includes ALAG): Kukaklek Lake, Battle Lake, Dakavak Lake
LACL: Twin Lakes, Telaquana Lake

Sampling within lakes and streams will be based on a combination of targeted and random selection procedures. Surface hydrology and freshwater chemistry data, in part, will be collected at the main outlet streams for the Tier 1 lakes and at bridge crossings for the Tier 1 river systems in KEFJ, whereas related data will be gathered at the deepest point of each lake. A generalized random-tessellation stratified design (GRTS; Stevens and Olsen 2004) will be used to select feeder streams in sampled lakes for collecting discharge and water chemistry data. This design also will be used to select net locations for sampling resident lake fish. Tier 2 and/or Tier 3 lakes or rivers will be stratified by lake size, water type (clear, glacial, brown), and accessibility prior to selecting a GRTS sample from the Tier 2 or 3 list. Sampling within Tier 2 or 3 locations will follow the same sampling protocols as those used in Tier 1 lakes and rivers.

Background information on spatial and temporal variability of the freshwater vital signs within these parks is limited. To determine the appropriate sampling interval, intensive sampling will occur during the initial implementation of this protocol, particularly in Tier 1 systems. Following the third year of sampling, data analysis will determine the sampling frequency for long-term monitoring.

During development of this protocol, the potential for integration with monitoring for other vital signs will be considered. In particular, co-location of tributary streams monitoring and core vegetation plots is likely.

<u>Surface Hydrology</u>

Stream flow will be estimated for targeted streams using acoustic Doppler current profile (ADCP) technology (Simpson 2001) and lake level measurements. ADCP is well suited for large, fast flowing rivers, such as the outlet streams for Tier 1 lakes (Tim Brabets, USGS, personal communication). Unfortunately, equipment and training for this method is expensive. USGS charges for stream gaging are also quite high (> $32,000/yr per stream), reflecting the logistical challenges in access. Brabets (2002) found a good relationship ($r^2 = 0.98$) between lake levels in Lake Clark and discharge in the Newhalen River. We are currently developing a cooperative agreement with USGS to assess this methodology for estimating stream flow in other Tier 1 outlet streams. If proven feasible, SWAN or park staff would record lake levels, whereas USGS would provide stream profiles and ADCP discharge measurements on a 2-5 yr basis.

Stage level is continuously recorded at Exit Creek and the Resurrection River by the National Weather Service River Forecast Office, with data available at (http://aprfc.arh.noaa.gov/cgi-bin/ahps.cgi?pafc&resa2).

<u>Freshwater Chemistry</u>

Continuous recorders (YSI 6600 or 6920) for temperature, pH, dissolved oxygen, conductivity, and turbidity will be placed in the Naknek River (KATM), in Exit Creek (KEFJ), and in the Newhalen River (LACL) following USGS protocols (Wagner et al. 2000). Temperature data logger (Onset HOBO and TidBit) strings will be anchored in midlake at ice out, and retrieved in late fall. In midsummer, lake profiles for the same parameters plus Secchi depth will be measured at the deepest part of the Tier 1 lakes (Gorransson et al. 2004). During implementation, measurements will be taken every 3 wk during the openwater season and at more than one location in the lakes (e.g., Chamberlain 1989, Wilkens 2002) to ensure that sampling is representative. Previous studies have shown SWAN lakes to be only weakly (Wilkens 2002, Chamberlain 1989) or discontinuously (LaPerriere 1997) stratified, and Wilkens (2002) found that in some years, stratification only lasted through July. Surface water samples, collected concurrently, will be analyzed for total phosphorus, total nitrogen, chlorophyll a, dissolved organic carbon, alkalinity, and a suite of selected major ion and trace elements. Temperature data, core parameters, and water chemistry samples will also be collected in selected inlet streams. Protocol will be guided by USGS methods and include a quality assurance plan and SOP for data entry into STORET.

<u>Resident Lake Fish</u>

Species Occupancy and Relative Species Richness. We will use beach seines and multimesh gill nets (Appelberg 2000) to sample resident fish species in selected lakes every 3–5 yr, where lake selection will additionally be restricted to those with a boat available for sampling. Netting effort will be standardized and recorded for each net location. Each lake first will be stratified by shoreline slope, and then these strata will be stratified further by distance to nearest tributary. A GRTS sample will be chosen from each stratum to identify net locations. We will use catch data in robust design, mark-recapture models (Pollock 1982) to estimate both occupancy (MacKenzie et al. 2003) of key species and relative species richness (Cam et al. 2000) of resident fish communities within selected SWAN lakes across time. Relative species richness is the ratio of resident fish species present in a given lake to the maximum number present in the relevant flow system. Year will be the primary occasion and net location will be the secondary occasion in the robust design framework. These mark-recapture approaches adjust for incomplete detectability at individual (occupancy) and species (relative richness) levels during sampling periods.

Biocontaminants. Alaska Department of Environmental Conservation (ADEC) has been collecting and analyzing fish in Alaska for baseline information on contaminant levels since 2001. During protocol development activities in LACL in 2005, SWAN collected and prepared a sample of resident fish species as per ADEC protocol and submitted them to ADEC for analyses. ADEC had agreed to pay for laboratory analyses. SWAN will pursue establishment of a similar agreement with ADEC or other relevant agency to analyze subsets from future samples of resident fish.

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<u>Surface Hydrology</u>

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<u>Freshwater Chemistry</u>

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<u>Resident Fish</u>

- Dan Young, NPS-LACL
- Troy Hamon, NPS-KATM
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Development Schedule, Budget, and Expected Interim Products:

<u>Surface Hydrology</u>

2006 Initiate cooperative agreement with USGS ($60,000).

2007 Develop draft protocol ($25,000).

2008 Implement and test ($25,000).

2009 Peer review and finalize ($25,000).

Freshwater Chemistry

2006 Develop and test draft protocol ($100,000).

2007 Implement protocol ($100,000).

Resident Lake Fish

2005 Draft SOPs ($15,000).

2006 Test protocols ($20,000).

2007 Implement protocol ($25,000).

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